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VISUAL CODING OF A COMPLEX ARRAY OF ON AND OFF STIMULUS PATTERNS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Visual Coding of a Complex Array of On and Off Stimulus Patterns" submitted by Ronald D. Handley in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Sixteen male university students were tested for recognition of and reaction to a visual display of four lights arranged in a square. Combinations of light on/off patterns were numerically coded from zero to fifteen. The stimulus light pattern was self-initiated and as soon as the S recognized the pattern he responded by depressing the appropriate number key on a panel before him.

Subjects were randomly assigned to four treatment groups: a light-on, changed stimulus group; a light-on, unchanged stimulus group; a light-off, changed stimulus group; and a light-off, unchanged stimulus group. Each S participated in eight sessions, six trials of each pattern per session.

The experimental design was a three-factor split-plot arrangement. The single dependent variable was decision time.

The experiment yielded a highly significant difference between stimulus patterns. It was concluded that Ss appeared to be processing sequentially in this task. The direction of the results indicated that in a complex task the changed stimuli will result in a faster decision time than unchanged stimuli.

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CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

Various attributes of both stimulus and response are known to affect reaction time which has been used as a principle measure of human processing time. Craik (1947), Hyman (1953) and Morin and Grant (1955) have shown that for a more complex stimulus, longer reaction times can be expected. Fitts and Deininger (1954) and Fitts and Seeger (1953) indicate that both stimulus and response codes are factors to be considered in choice reaction times.

Mowbray (1960) and Mowbray and Rhoades (1959) have demonstrated the ability of humans to substantially reduce choice reactions with practice. More interestingly, Fitts and Seeger (1953) as well as showing this trend, have shown that over a three-month period the highly compatible stimulus response codes continued to result in better performance than less compatible stimulus response codes. This would seem to imply that humans process information sequentially or serially; indeed, the idea has been in the literature since the time of Donders in 1868 (Biederman and Kaplan, 1970). Neisser (1963) however, presents information which indicates that man can process information simultaneously.

Yet another aspect of reaction time as a measure of human processing time is the readiness or anticipation for

the stimulus by the appropriate receptors. Simon, Craft and Webster (1971) indicate that there exists in humans a marked tendency to react toward the source of stimulation. With visual stimuli various factors such as the light intensity and exact area of the eye stimulated have created ambiguity in the results of other studies which examined whether Ss reacted faster to changed or unchanged stimuli, or whether Ss reacted faster to "on" or "off" stimuli. To date, no studies have been reported which examined the effect of changed or unchanged stimuli when the task required of the S was complex.

Photoreceptors in the eye are now known to be organized into receptive fields. Kuffler (1953) found numerous receptive fields in the cat's retina that were either "on" or "off" center orientated with opposite type surrounds. That is, if a particular "on" center of a receptive field was stimulated by a flash of light it immediately sent a discharge pattern to higher centers. An "off" center receptive field required a light stimulus to be ceased for it to fire. Hubel and Weisel (1959, 1961, 1962, 1965, and 1968) have extensively examined the receptive field geometry of the visual system. While their major contribution has been from investigation of higher order receptive fields such as those in the lateral geniculate body and visual cortex, the "on"-"off" characteristics are indicated throughout.

Purpose of the Study

In a pilot study, Wilberg and Handley (1971) examined human processing time as a function of the nature and complexity of the stimulus within certain limits. The stimulus was either an "on" stimulus or an "off" stimulus and the task was such that Ss were required to decide which of sixteen stimuli was being presented. The study supported the notion that Ss processed information more in a sequential manner than in a simultaneous one. In the study Ss reacted faster to lights coming on than to lights going off. The significance of these trends decreased as learning between test trials decreased.

An examination of the effect on processing time of all combinations of "light on-off" stimuli at a criterion level of learning is the primary basis for the present study. The present experiment is the logical progression of the Wilberg and Handley study.

The Problem

It was the purpose of this study to examine the effects of certain factors on processing time in a choice situation. The factors chosen were: complexity of pattern of each stimulus, nature of the stimulus in terms of light coming on or going off, nature of the stimulus in terms of the change of the stimulus, and rates of learning over trials for the different stimulus treatment groups.

Definition of Terms

Decision time (DT). Upon a ready signal S prepared himself, then depressed a microswitch thereby creating a stimulus. As soon as S knew which stimulus pattern was being presented he released a microswitch and responded towards an appropriate numbered microswitch. Decision time is considered to be that time required for S to process the stimulus as determined by the length of time the initiating microswitch remained depressed.

Movement time (MT). Movement time is that time elapsed between the release of the center microswitch and the depression of the appropriate numbered microswitch.

Processing. In experimental psychology, processing is a term used to describe the general concept of the brain's organization, assimilation and effectuation of stimulus information.

Light on stimulus/Light off background (LON_c). Treatment condition in which the appropriate stimulus patterns were the lights which came on.

Light on stimulus/Light on background (LON_u). Treatment condition in which the appropriate stimulus patterns were the lights which remained on.

Light off stimulus/light on background (LOF_c). Treatment condition in which the appropriate stimulus patterns were the lights which went off.

Light off stimulus/Light off background (LOF_u). Treatment condition in which the appropriate stimulus

patterns were the lights which remained off.

<u>Stimulus patterns (SP0, SP1, . . . SP15)</u>. Any light or combination of lights in a four-light display could be controlled by <u>E</u> to either come on or stay off. The sixteen combinations of the four lights are the sixteen stimulus patterns used in this experiment.

CHAPTER 2

REVIEW OF THE LITERATURE

This review is delimited to studies of onset and offset reaction time, and to relevant studies on the question of how humans process information. For an overall review of the characteristics and implications of reaction time studies, some pertinent monographic sources are: Fitts and Posner (1967); Smith (1968); and Teichner (1954).

RT to Onset and Cessation of Visual Stimuli

RT studies to the onset and cessation of stimuli began just after the turn of the century. Wells (1913) and Woodrow (1915) agree that there is no appreciable difference between onset RTs and cessation RTs. Woodrow's study had the added dimension of several levels of light intensity with still no appreciable differences occurring. Others (Jenkins, 1926; Pieron, 1927; and Steinman, 1944) have concluded that, contrary to Woodrow's findings, RTs obtained by stimulation of low luminance levels, are faster to offset than to onset stimuli.

Rains (1961) examined RT to onset and cessation of a bright, large flash against a dark background and found no difference but did suggest that ". . . differences may be apparent when a small, dim, peripheral flash is employed."

Pease and Sticht (1965) examined the luminance and

foveal-periphery influences on onset and offset RTs. While the offset-onset factor was not significant, luminance value was highly significant. The foveal-periphery factor analysis indicated that the RTs to offset stimuli in the foveal area were faster than onset, but in the periphery the opposite occurred. Pease and Sticht's results aid in the explanation of some of the earlier discrepencies. That is, with low or moderate luminance the offset RTs can be faster than the onset RTs if the area stimulated is the fovea, however ". . . the difference (offset faster than onset) may be eliminated or even reversed, by increasing luminance of the stimulus to a high level."

Bartlett, Sticht and Pease (1968) measured onset and offset RTs to two wavebands (red and blue) in both the fovea and periphery. Their findings confirmed the previous conclusions regarding quicker onset RTs in the periphery; that is, the peripheral system yielded faster RTs to onset than to offset stimuli of both wavebands. There was no significant difference between onset and offset RTs to stimuli of either waveband in the foveal region.

The finding that in the periphery the onset RTs are faster than offset RTs provides behavioral evidence for the electroretinogram studies which indicate that the off effect is far more conspicuous in cones than in rods (Granit, 1955).

Pursuing a behavioral course Versteeg (1970) studied onset and offset RT variability as a function of the proximity to a border in a visual field, in hopes of providing evidence

for the contrast-boundaries perceptual problem usually labelled as a lateral inhibition phenomenon:

> Border contrast effects are most frequently attributed to lateral inhibitory processes in the retina. Each element in the retinal mosaic inhibits the activity of its neighbors to a degree that is greater the more strongly it is excited. Thus a group of receptors that are within the region of high illumination but close to the border will receive less inhibition than a group of receptors that are well inside the region where all of the closely neighboring receptors are brightly lighted.

Indeed, Versteeg did find this to bear out in his study. Subjects generally appeared to be faster to offset stimuli than to onset stimuli, however, the result was not statistically significant.

Simon, Craft and Webster (1971) comment on evidence in information processing studies which seems to indicate that there exists in humans a marked tendency to react toward the source of stimulation:

> There seems to be an initial tendency to react to the source of a stimulus rather than to its meaning, and the necessity for overriding this initial response tendency produces the observed delay in information processing.

Simon, et al. had _S_s respond to the onset or offset of one light in a simple two-light display. After examining reactions under the four conditions of on and off, they concluded that reactions were faster to the element of the display which had changed.

In this study onset RTs were considerably faster than offset RTs (320 msec for onset--578 msec for offset); yet, Simon, et al. are quick to warn against using their data to make such a comparison without considering rise times. While

the apparatus section of their report is not elaborate enough to enable calculation of such important times, it seems unlikely that rise and decay times will account for the difference of 258 msec.

In the studies mentioned above, with the exception of that by Simon, et al., the RTs could be classified as simple. The direction of onset and offset RTs have yet to be fully explored in choice situations.

Information Processing Behavior

There exists in the psychological literature several notions concerning the manner in which humans process information and arrive at decisions required by choice situations. Most recently, a controversy has arisen as to whether or not the processing, or discrimination between multi-dimensional objects is accomplished by comparing the objects one dimension after the other (serial mode) or by comparing the objects on several dimensions simultaneously (parallel mode).

Based on the research directed at resolving the issue of serial versus parallel processing, numerous studies provide evidence in support of serial processing (Briggs and Blaha, 1969; Burrows and Murdock, 1969; Egeth, 1966; Harris and Haber, 1963; Lethio, 1970; Olshavsky and Gregg, 1970; and Sternberg, 1966). However, and equivalent body of research has been carried out which supports parallel processing (Donderi and Zelnicker, 1969; Egeth and Pachella, 1969; Hawkins, 1969; Neiser, 1963; and Tulving and Lindsay, 1967).

The evidence which favors one processing mode over the other, plus the evidence which cannot support either processing system (Atkinson, Holmgren and Juola, 1969; Lindsay and Lindsay, 1966; and Sekuler and Abrams, 1968) has created a renewed interest in the study of the relevant variables of the processing experiments.

For example, Garner (1970) states:

> The role of the stimulus needs to be studied, and concepts based on stimulus properties must be evolved before we can truly understand how the organism processes information.

Bindra, Donderi and Nishisato (1968) have demonstrated the importance of the codability of stimulus dimensions as an important factor in determining whether same judgments are faster than difference judgments.

Orenstein (1970) studied the effects of stimulus discriminability, stimulus frequency and response frequency in a choice reaction time task and found that stimulus frequency and discriminability were most influential in determination of the CRT. Fitts and Deininger (1954) and Fitts and Seeger (1953) stressed the importance of stimulus and response codes in choice reaction tasks.

Grill (1971) has indicated that under certain conditions of task complexity and practice a gradual shift from serial to parallel processing can occur. Similarly, Townsend (1971) suggests that for some psychological systems S may be able to manipulate the manner in which he distributes processing energy over the elements to be processed ". . . if not within a single trial, perhaps from trial to trial."

Thus _S_ might proceed from a serial to a parallel processing system.

The notion that humans can process information both serially and simultaneously is not unsubstantiated. Neiser (1967) proposed an hierarchical model in which decisions can be carried out simultaneously at each level of the hierarchy, while they occur serially at different levels. Marcel (1970) states: "One may attend to events simultaneously if they are on two functionally separate channels, but not if they are on functionally the same channel."

The "state of affairs" in this field of research is perhaps most appropriately summed up by Grill (1971):

> On the basis of the results of previous research, it seems fairly obvious that expecting to resolve the categorical issue of serial vs parallel processing is at least unrealistic if not unwarranted. Instead, it would appear that the most profitable direction for research would be to ascertain the factors that are potential sources of variation . . .

CHAPTER 3

METHODS AND PROCEDURES

Experimental Design

A three-factor split-plot design was used in this experiment. The between factor consisted of the four conditions of the light stimulus (LONc, LONu, LOFc, and LOFu). Trials and stimulus patterns were the two within factors of the experiment. The single dependent variable was DT.

The following analyses were performed on the DT data:

1. Analysis of variance--Treatments by Patterns by Trials.
2. Duncan's Multiple Range Test--Stimulus Patterns.
3. Analysis of variance--*Ss* by Trials by Patterns (Patterns ordered by stimulus value).
4. Analysis of variance--*Ss* by Trials by Patterns (Patterns ordered by actual combination of lights on and off).

The alpha = 0.01 level of rejection was used for all tests.

Subjects

Sixteen male University of Alberta students were *Ss* in this experiment. All *Ss* were right-handed and had no apparent visual or motor impairment.

Apparatus

A sturdy response panel which consisted of a centered microswitch and sixteen equidistance microswitches numbered from zero to fifteen, was bolted to a table (see figure 1). A stimulus box containing four lights was placed on the wall directly in front of, and at a distance of five feet six inches from the center of the response panel (see figure 2). Electric circuits were arranged such that any combination of the four lights in the stimulus box could be preset by E from his control position (see figure 3).

The power supply to the four lights was via an Electro Model NFRB Filtered DC Power Supply. Voltage to the light source (four GE 50 bulbs) was kept constant at nine volts.

The four light stimuli subtended a visual angle of approximately two degrees.

By means of a relay switch (1R-640V-2C-120A GE All Purpose Relay) and two latching relay switches (1R-640L-C115 GE Latching Relay) it was possible for S to initiate the stimulus preset by E. Two Hunter Thousandth Second Clock Counters were used to measure the elapsed time for recognition of the pattern, DT, and the elapsed time for the S to move to the appropriate number key, MT.

Four latching relays enabled E to set the ambient condition of the stimulus box to either all lights on for the LONu and LOFc experimental groups or to all lights off for the LONc and LOFu groups.

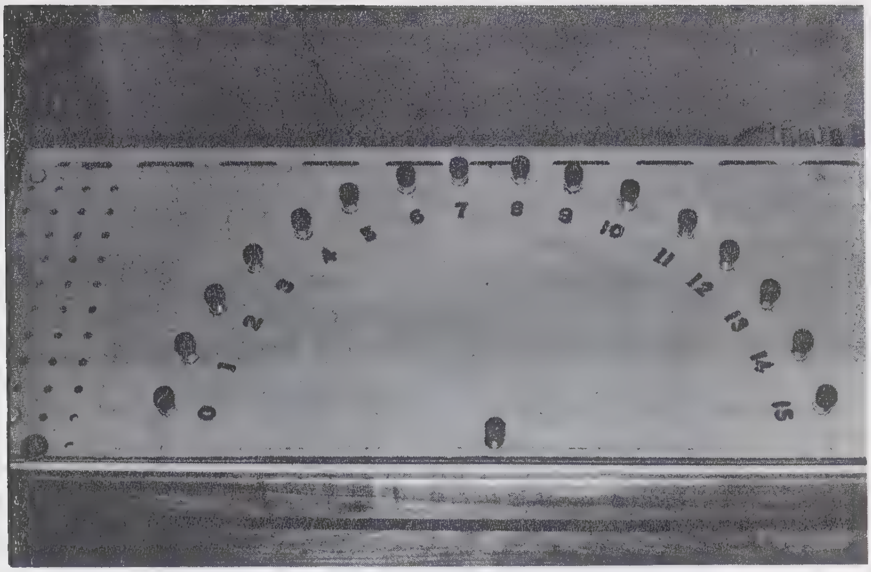


Figure 1

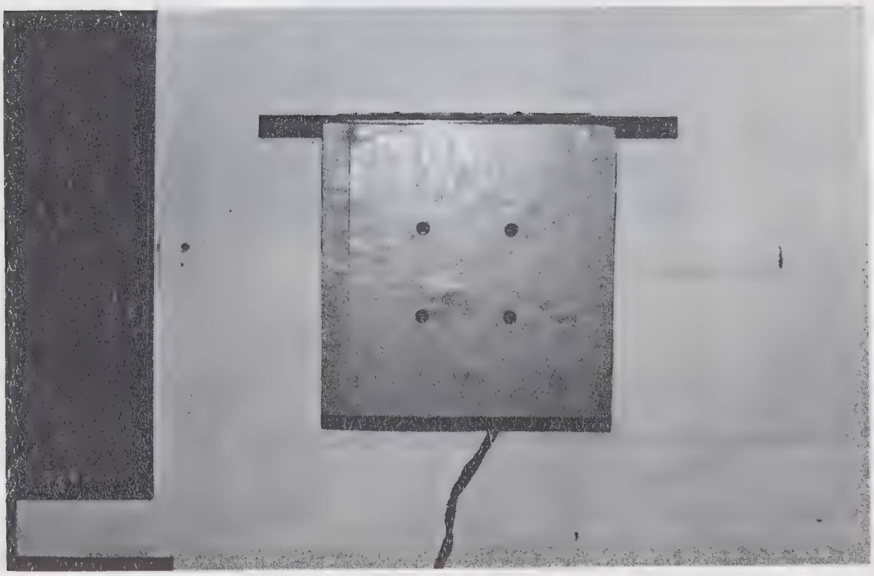


Figure 2

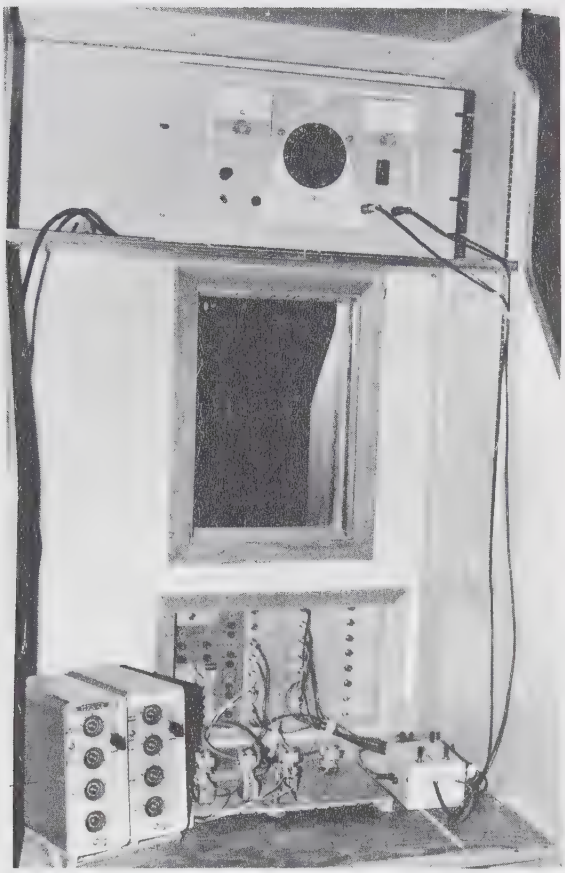


Figure 3

Table 1

STIMULUS-RESPONSE CODES

Stimulus Pattern		Treatment Group			
		LONc	LOFu	LONu	LOFc
SP0	oo oo	0	15	0	15
SP1	oo -o	1	14	1	14
SP2	-o oo	2	13	2	13
SP3	-o -o	3	12	3	12
SP4	o- oo	4	11	4	11
SP5	o- -o	5	10	5	10
SP6	-- oo	6	9	6	9
SP7	-- -o	7	8	7	8
SP8	oo o-	8	7	8	7
SP9	oo --	9	6	9	6
SP10	-o o-	10	5	10	5
SP11	-o --	11	4	11	4
SP12	o- o-	12	3	12	3
SP13	o- --	13	2	13	2
SP14	-- o-	14	1	14	1
SP15	-- --	15	0	15	0

- = light on
o = light off

Each S received six randomly arranged presentations of each pattern, preset by E, in a single session. The E monitored DT, movement time and correctness of response on the first five presentations each session, and recorded the DT on the sixth trial. Each S participated in eight sessions. The first seven sessions were considered training sessions. Data for the experiment was recorded during the last three trials in the eighth session.

CHAPTER 4

ANALYSIS

Hypotheses

Based on a review of the literature and following directly from the problems of this experiment as stated in Chapter 1, five hypotheses were formulated:

H_1: SP0 = SP1 = . . . = SP15

H_2: LONc = LONu = LOFc = LOFu

H_3: LONc + LOFc = LONu + LOFu

H_4: Learning curves to be similar for each treatment group

H_5: Trial 46 = trial 47 = trial 48

Decision time measured in milliseconds was the dependent variable for these hypotheses.

The first hypothesis was stated in the null form as the review of literature revealed a controversy between serial and parallel systems of information processing. Also, the kind of processing which would occur in the present task was not predictable on the basis of the stimulus properties, in that no previous study had used an analagous stimulus presentation.

The second hypothesis was stated in the null form as the evidence in the literature is inconclusive with regards to reaction to onset and offset stimuli especially under choice situations.

Faster reactions to the changed element of a display has been demonstrated by Simon,et al. (1971). However, it is felt their study was insufficient proof for stating the third hypothesis in other than the null form.

Hypothesis four was stated in the null form because of an absence of any prior publications concerned with learning rates under conditions present in this experiment.

The fifth hypothesis was stated in the null form as it represented the criterion level of learning for the study. A rejection of this hypothesis would indicate that Ss were not consistent enough at this stage of their practice.

Results

A three-way analysis of variance was computed and is summarized in Table 2. As this experiment involved replications,assumptions underlying the analysis of variance may have been violated. Geisser and Greenhouse (Edwards, 1968) have shown the effect on the degrees of freedom by the maximal amount. Assuming maximal violation of those assumptions in the present study, the conservative test of Geisser and Greenhouse has been used where applicable. Reactions to the sixteen stimulus patterns yielded the only significant F ratio in the analysis.

Treatment groups were combined to examine whether Ss responded faster to changed or unchanged stimuli. The results of this second three-way analysis is summarized in Table 3. Once more, only the stimulus patterns effect was significant.

TABLE 2

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE. FOUR LON/LOF TREATMENT GROUPS

SOURCE	SS	df	Con.df	MS	F
Treatments (A)	386816	3	3	128938	0.16
S(A)	939750	12	12	783125	
Trials	116736	2	1	58368	4.45
Trials by Treatments	72192	6	3	12032	0.92
Trials x S(A)	314624	24	12	13109	
Patterns	14691584	15	1	979438	21.1**
Patterns x Treatments	2043904	45	3	45420	0.98
Patterns x S(A)	8354816	180	12	46415	
Trials x Patterns	458752	30	1	15291	1.32
Treatments x Trials x Patterns	897024	90	3	9966	0.86
Trials x Patterns x S(A)	4177152	360	12	11603	

$^{**}p<0.01$

TABLE 3

SUMMARY OF THREE WAY ANALYSIS OF
VARIANCE - CHANGED OR UNCHANGED

SOURCE	SS	df	Con.df	MS	F
Treatment (A)	192768	1	1	192768	0.28
S(A)	9591552	14	14	685110	
Trials	116736	2	1	58368	5.00
Trials x A	60416	]	1	30208	2.59
Trials x S(A)	326912	28	14	11675	
Patterns	14691584	15	1	979438	20.52**
Patterns x A	376064	15	1	25070	0.53
Patterns x S(A)	10022656	210	14	47726	
Trials x Patterns	458752	30	1	15291	1.36
Treatments x Trials x Patterns	367104	30	1	12236	1.09
Trials x Patterns x S(A)	4713728	420	14	11223	

** $p < 0.01$

In an effort to determine the nature of the significant patterns effect, a three-way analysis of variance, Patterns by Ss by Trials, with the patterns grouped as per actual stimulus rather than stimulus value, was computed. The results of this analysis are summarized in Table 4. Table 4 also contains a summary of the analysis for Ss by Trials by Patterns with the patterns ordered by stimulus value. Paterns, Ss and the Patterns by Ss interaction were significant factors regardless of how the patterns were ordered.

The difference between stimulus patterns when ordered by stimulus value was anlayzed by Duncan's New Multiple Range Test. This test is illustrated in Table 5.

Discussion

Stimulus patterns. The patterns effect as indicated in Table 2 was highly significant. Consequently, the first hypothesis, which was stated in the null form, was rejected.

At the completion of testing Ss invariably reported that they felt they were responding equally to all patterns; that they no longer sampled each element of each stimulus but rather responded to the configuration of all four lights. If this were so, one might suspect that Ss were simultaneously processing all four elements of the display. DTs between patterns should be approximately the same. The analysis does not support the Ss subjective reports. In fact, a very large difference did occur between DTs for the different patterns.

TABLE 4

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE
STIMULUS PATTERNS ARRANGED BY NUMERICAL VALUE

SOURCE	df	Con.df	MS	F
Patterns (PAT)	15	1	979469	86.41**
Trials (TRI)	2	1	58556	5.16
PAT x TRI	30	1	15346	1.35
SUBJECTS (S)	15	15	652323	57.55**
PAT x S	225	15	46245	4.08
TRI x S	30	15	12945	1.14
ERROR	450	15	11334	

** $p<0.01$

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE
STIMULUS PATTERNS ORDERED BY ACTUAL STIMULUS

SOURCE	DF	Con.df	MS	F
Patterns (PAT)	15	1	487371	41.87**
Trials (TRT)	2	1	58556	5.03
PAT x TRI	30	1	10779	0.92
Subjects (S)	15	15	652323	56.04**
PAT x S	225	15	79051	6.79
TRI x S	30	15	12945	1.11
ERROR	450	15	11639	

** $p<0.01$

TABLE 5

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO THE DIFFERENCE

BETWEEN DT MEANS FOR THE STIMULUS PATTERNS

Stimulus Pattern	15	0	1	2	8	3	4	6	12	9	14	5	7	10	11	13
DT (msec)	534.6	537.9	549.5	630.5	655.6	661.9	663.4	750.1	756.3	794.8	823.7	857.3	859.0	881.3	930.8	987.1
							128.8	200.6	125.8	131.4	160.4	193.9	195.6	131.2	136.0	128.1

Stimulus Pattern: 15, 0, 1, 2, 8, 3, 4, 6, 12, 9, 14, 5, 7, 10, 11, 13

SHORTEST SIG RANGES

R2 = 113.4
R3 = 118.2
R4 = 121.4
R5 = 123.8
R6 = 125.8
R7 = 127.4
R8 = 128.7
R9 = 129.9
R10= 130.9
R11= 131.8
R12= 132.6
R13= 133.4
R14= 134.1
R15= 134.7
R16= 135.3

Significant difference (0.01 level) for any pair of means not underscored by a single line.

The manner in which Ss did perceive the sixteen patterns has interesting implications in terms of the simultaneous-sequential processing controversy. The results of the study might be taken as supportative for the sequential theorists in that, as seen in Table 5, three position (SPs 7, 11, 13 and 14) stimuli had longer DTs than did two position stimuli, which in turn had longer DTs than did one position stimuli. However there is conflicting evidence in that SPs 5 and 10 (two position stimuli) were in the three position stimuli grouping, and the four position stimuli (SPs 0 and 15) were quickest of all. Yet the apparent conflict with the sequential theory is not valid, for if Ss were processing sequentially one would expect the results which occurred. For example, if Ss sampled the perimeter of the square, and presumably could go in any horizontal or vertical direction from the first critical element they sampled, it seems reasonable that SPs 5 and 10 should take as long as SPs 7, 11, 13 and 14 since the scanning system would have to cover the same number of elements since SPs 5 and 10 are the diagonal stimuli. Similarly, with the four position stimuli there are basically no critical elements thus the comparator mechanism would not have to be searched for elements and one would expect faster DTs for SPs 0 and 15 (See Appendix).

RT has been shown to be biased by frequency of stimulus (Orenstein, 1970). In the present experiment, since each pattern occurred an equal number of times in a random fashion, Ss were unable to predict which stimulus would be

presented. However, there necessarily occurs an imbalance in frequency for one position, two position, three position and four position stimuli patterns. In a trial run of the sixteen patterns one position patterns occur four times (SPs 1, 2, 4, and 8); two position patterns occur six times (SPs 3, 6, 9, 5, 10, and 12); three position patterns occur four times (SPs 7, 11, 13 and 14); and four position stimuli occur twice (SPs 0 and 15). Any stimulus bias which might occur with increased frequency of the two position patterns is perhaps negated by the increased uncertainty of which of the two light patterns are being presented. In other words, an explanation of SP differences here does not appear to have a frequency or probability basis.

The arrangement of mean DTs, as in Table 5, also rules out the possibility that the difference between patterns is due to numeration alone. For example, SP15 had the lowest DT of all patterns; SP8 had a mean DT less than SPs 3, 4, 5, 6, and 7; and SP 12 had a lower mean DT than SPs 9, 5, 7, 10, and 11.

The arrangement of means from fastest to slowest indicates that if a classification for the patterns could be formed, then it would be most probably on a basis of the number of critical elements in any particular stimulus pattern. Thus, SP 1 has one critical element and should have a mean DT quicker than a two element pattern such as SP 9, similarly, SP12 would have a mean DT quicker than the mean DT for SP7, a three element pattern. With the exception of

SPs 5 and 10, this categorization appears to be substantiated. Thus the results fit fairly well into the hierarchical model of Neisser (1967), and a similar model of Marcel (1970). If the SPs are grouped by number of critical elements the mean DTs for each group are reasonably equivalent, suggesting a simultaneous mode of processing. It is not important where the critical items are located, merely how many critical items occur in each presentation. Presumably all one element patterns should be processed equally fast, as should the two element patterns and so on. The results then fall in line with the theory that in a CRT task the more items to be monitored and decided upon, the longer the decision process.

As can be seen in Table 1, actual stimulus presented and stimulus value are not the same for each treatment group. To this point, the patterns effect discussion has been entirely with regards to stimulus value. In Table 4, the reader can compare the summaries of the analysis for the experiment when patterns were ordered by stimulus value and when patterns were ordered by actual stimulus presented. The stimulus value interpretation appears to be the correct one for this experiment for two reasons. First, the mean square for the patterns effect is larger when patterns are ordered by stimulus value. Secondly, the patterns by Ss interaction is larger when patterns are ordered by actual stimulus. However, the large F ratio for the patterns effect resulting when patterns

are ordered by actual stimulus cannot be ignored. It is evident that Ss were perhaps optimizing under certain conditions and not operating strictly according to their instructions. For example, it is quite probable some Ss in the LOFu group would be recoding some of their patterns and responding similarly to the LONc group. This could account for the large degree of S variability in the experiment.

Light on/off stimuli. The experiment did not indicate a significant difference between on-off stimulus treatment groups. Consequently, the second hypothesis, which was stated in the null form, was not rejected.

Evidence from Pease and Sticht (1965) implicates that offset reaction, for the foveal area at least, should be quicker than reaction to onset stimuli. Contrary results were indicated in the pilot study. There are perhaps several plausible explanations for the non-significant difference between groups in the present experiment. Firstly, this study involved a complex stimulus which meant Ss had to make one of sixteen decisions for each presentation, whereas in the Pease and Sticht experiment the task was strictly simple. Thus it is quite possible that any true difference between onset and offset reaction is negated by the increased processing time required in a choice situation.

Secondly, four treatment groups were used in this experiment as compared with two (LONc and LOFc) in the pilot study.

Thirdly, the primary analysis was conducted at a later learning stage than in the pilot study. Consequently Ss would presumably be better practiced, thus operating at close to their minimum processing time and differences between groups would be harder to detect.

Fourthly, S variability as indicated by the highly significant F ratios in Table 4, would undoubtedly hinder the possibility of detecting a difference between groups unless the differences were very large.

While no difference between humans' capacity to respond to onset and offset stimulation can be concluded from this study, it is interesting to note that Ss in the LONc group on the whole reacted faster than did Ss in the other groups. Mean DTs for each group are indicated in Table 6. The direction of these results are in agreement with the pilot study.

Change versus unchanged stimuli. As there was no significant difference between groups who responded to the changed elements of the display and the groups who responded to the unchanged elements of the display, the third hypothesis, which was stated in the null form, was not rejected.

In the Simon, Craft and Webster (1971) experiment Ss reacted faster to the changed element in both onset and offset trials. On onset trials, reactions were faster toward the light which went on than toward the light which remained off. On offset trials, reactions were faster toward

TABLE 6

MEAN DTs FOR TREATMENT GROUPS

	LOFc	LONu	LONc	LOFu	MEAN
SPO	526.0	516.5	505.4	603.7	537.9
SP1	546.8	552.2	502.0	597.2	549.5
SP2	553.7	729.9	602.1	636.2	630.5
SP3	646.3	707.4	633.9	660.0	661.9
SP4	629.2	669.7	617.5	737.4	663.4
SP5	975.4	850.3	776.3	827.3	857.3
SP6	763.3	760.2	701.5	775.5	750.1
SP7	858.3	954.0	845.4	778.5	859.0
SP8	703.3	640.5	594.9	683.8	655.6
SP9	772.0	778.1	743.2	885.9	794.8
SP10	1008.8	814.1	830.0	872.3	881.3
SP11	914.8	1000.9	931.0	876.6	930.8
SP12	714.8	758.8	732.5	819.1	756.3
SP13	924.5	1108.0	981.6	934.4	987.1
SP14	825.1	972.0	816.6	681.2	823.7
SP15	559.8	510.6	504.8	563.1	534.6
MEAN	744.7	769.8	707.0	745.4	

the light which went off than toward the light which remained on. An examination of the treatment group means in the present experiment indicates a similar organization, although not significant. Average DT for Ss in the LONc group was 707 msec as compared to 745.4 msec for Ss who responded to the lights which remained off. Similarly, the average DT (744.7 msec) for Ss in the LOFc group was faster than the average DT (769.8) for the group of Ss which responded to the lights which remained on (see Table 6).

While the phenomenon of Ss reacting quicker to the changed element of the display has been demonstrated through an examination of means it probably was not statistically significant in the analysis because of the large S variability and the relative lack of power for the between factor of a split plot arrangement.

Quicker reactions to the changed element of a stimulus is an important motor performance consideration.

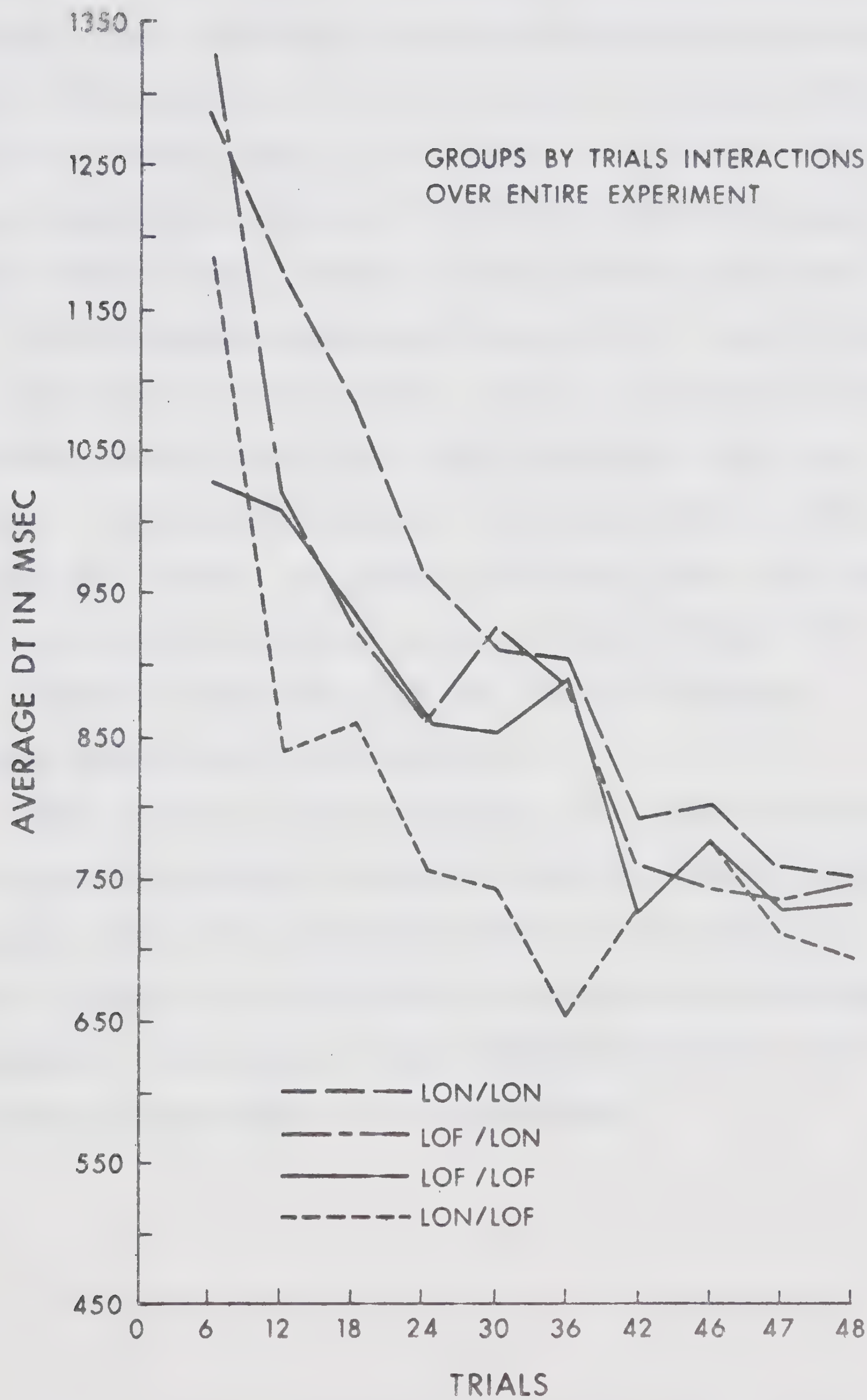
Trials. Learning over trials did occur, as expected, however the learning curves for treatment groups did not differ significantly consequently the fourth hypothesis, which was stated in the null form, was not rejected. Table 7 is a summary of the analysis of groups by patterns by all trials. There was not a significant groups by trials interaction. The learning curves for the treatment groups are illustrated in Figure 4. While no significant difference was indicated between learning curves, examination of Figure 4

TABLE 7

SUMMARY OF THREE WAYS ANLYSIS OF VARIANCE - OVER ENTIRE EXPERIMENT

SOURCE	df	Con.df	MS	F
Treatment (A)	3	3	3211946	1.65
Subject (A)	12	12	1946517	
Trials (TRI)	9	1	5399068	25.87**
A x TRI	27	3	229006	1.10
TRI x S(A)	108	12	208727	
Patterns (PAT)	15	1	6879283	50.53**
A x PAT	45	3	164829	1.21
PAT x S(A)	180	12	136149	
TRI x PAT	135	1	180563	3.98
A x TRI x PAT	405	3	57275	1.26
TRI x PAT x S(A)	1620	12	45340	

** $p<0.01$


GROUPS BY TRIALS INTERACTIONS
OVER ENTIRE EXPERIMENT
AVERAGE DT IN MSEC
1350
1250
1150
1050
950
850
750
650
550
450
0
6
12
18
24
30
36
42
46
47
48
TRIALS
LON/LON
LOF /LON
LOF /LOF
LON/LOF

indicates that LONc group had quicker DTs throughout the experiment. That is, the LONc group reached criterion level earlier than other groups. This finding is in agreement with the finding that there was a significant difference between LONc and LOFc groups in the pilot study. Further examination of Figure 4 reveals that at the level of practice which the previous study was conducted (30 trials) the difference between LONc and LOFc groups is approximately 150 msec.

The difference between trials 46, 47, and 48, the final trials of the experiment, was not significant at the 0.01 level, consequently the fifth hypothesis was not rejected. The mean DT over all conditions for the 46th trial was 759.5 msec. The mean DT for the 47th trial was 734.4 msec and for the 48th trial the mean DT was 732.4 msec. Figure 4 indicates that DTs for the different treatment groups have levelled off.

What effect further practice would have on DTs for the different treatment groups can only be conjectured at this point. One very important effect which could be elicited is that Ss could become less variable thus enhancing E's chances of detecting a real difference between the treatment groups as studied in this experiment.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to examine the nature of processing with a complex task requiring sixteen stimulus-response codes, and the stimulus properties controlled to be either: a light coming on; a light remaining on; a light going off; or, a light remaining off. The experimental design was a three-factor split-plot factorial with one between and two within factors. Decision time in milliseconds was the single dependent variable. The subjects were sixteen right-handed male physical education students.

From a review of the literature five null hypotheses were formed:

1. That there was no significant difference between stimulus patterns, since essentially each pattern offered the same amount of information.

2. That there was no significant difference between light on-off stimulus treatment groups.

3. That there was no significant difference between treatments when grouped by changed and unchanged stimuli.

4. That there was no significant difference between learning curves for each of the four treatment groups.

5. That there was no significant difference between

Trials 46, 47, and 48 of the experiment.

The collected data were treated by analyses of variance and Duncan's New Multiple Range Test.

Conclusions

Of the five null hypotheses, only the first was rejected. It was concluded, following the multiple comparison of stimulus patterns that subjects were processing sequentially in this task.

While no significant difference was indicated between treatments, the subjects in the "light coming on" group had the quickest decision times and reached the criterion level soonest. The direction of the results also indicated that in a complex task the changed stimuli will result in a faster decision time than unchanged stimuli.

Further Direction

While subjects in this study had reached a criterion level of learning, further practice would inevitably reduce the high subject variability. Also recommended are the use of either more subjects per treatment group, or a different more powerful experimental design.

Utilization of more sophisticated apparatus such as an automatic stimulus changer and a paper punch recorder would enable subjects to attain a higher level of competency in a shorter time span.

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APPENDIX

Instructions to Ss in LONc Treatment Group

"Sit before the response panel such that your right hand is poised over the center initiating switch. Focus on the stimulus box. When you depress the center switch any combination of the four lights could come on or stay off. Your task is to code the patterns. The lower left hand light is equal to one, the upper left hand light is equal to two, the upper right hand light is equal to four, and the lower right hand light is equal to eight. Any combination of lights coming on, then, can be coded from zero to fifteen. For example, if the lower left and upper right lights come on the answer is five and you should respond as quickly as possible by releasing the center switch and depressing Number Key 5. It is extremely important that you react as quickly as possible, however you must not release the center switch until you have the answer. After each response call out which pattern you perceived and wait for my 'ready' signal before initiating the next stimulus."

Instructions to Other Treatment Groups

As above with the following exceptions:

1. Subjects in the LONu treatment group were told to respond to the lights which remained on.

2. Subjects in the LOFc treatment group were told to respond to the lights which went off.

3. Subjects in the LOFu treatment group were told to respond to the lights which remained off.

Critical Elements of SPs 0 and 15

If one considers there to be four critical elements that can change in the display, then for SP 0 there is essentially no change in any of the four critical elements and for SP 15 all four critical elements change. Presuming that the four lights could be seen at the same time (visual angle 2°) the decision required when all lights changed or did not change becomes the simplest of all 16 patterns. The choice for _S_ is, as in the "go-no-go" situation, to decide whether all lights had changed or no lights had changed.